

## THE MOUNT WASHINGTON (NEW HAMPSHIRE) HALO OF OCTOBER 4, 1933

By W. J. HUMPHREYS

The article in this number of the MONTHLY WEATHER REVIEW by Messrs. Robert G. Stone and Salvatore Pagliuca on the Mount Washington (N.H.) halo of October 4, 1933, deserves especial attention, since it gives an account of repeated measurements, by means of a theodolite, of a rare halo, one which, so far as I know, never was so carefully measured before, if indeed ever before measured at all.

The value obtained,  $23^{\circ}30'$  was, as stated by the observers, the angular distance from the inner edge of the

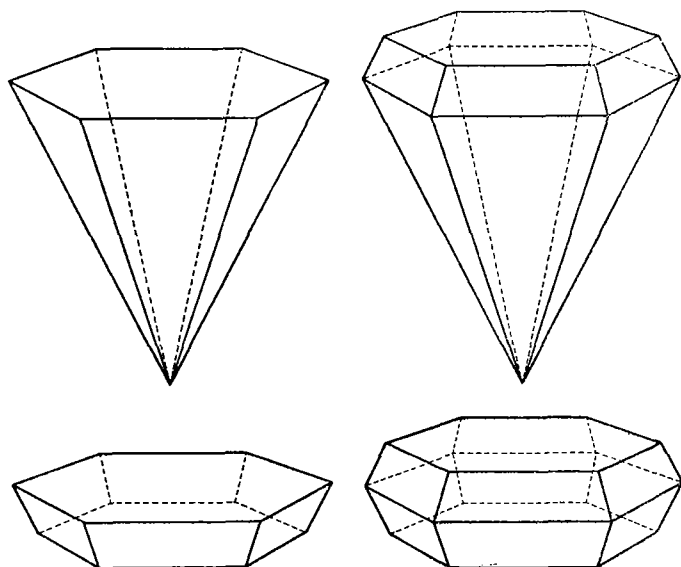


FIGURE 1.—Forms of snow crystals capable of producing the  $24^{\circ}34'$  halo.

halo to the nearest limb of the moon, whereas halos commonly are measured from the center of the moon, or sun, to about the middle of the yellow band (in the case of colored, or refraction, halos such as this one was) which itself is roughly half-way between the inner and outer edges of the halo.

If, therefore, the measurements of this halo had been from the center of the moon to about the middle of the yellow band the value found would have been appreciably greater than that gotten by the method followed, namely,  $23^{\circ}30'$ . This seems to exclude, as a possibility, the  $23^{\circ}24'$  halo, listed on page 517 of Humphreys' *Physics of the Air*, 2nd Edition, and computed for sodium yellow light, refractive index 1.31, and measured from the center of the luminary, sun or moon. That is, this halo is ruled out if the slope of the pyramidal face of the crystal to the longitudinal axis is  $24^{\circ}51'$  (adopted, after computation, in *Physics of the Air*), or thereabouts. It is further excluded by the fact that the occurrence of this  $23^{\circ}24'$  halo requires the presence of columnar crystals pyramidal at one end, or both, that would produce, by the columnar portion, the  $22^{\circ}$  halo also, which was not observed.

Suppose, therefore, that in the main the crystals had no columnar segments but were chiefly one or more of the unusual but well-known pyramidal types shown in figure 1; that is, a single right pyramid, truncated or not, or a double right pyramid, base to base, having one end, or both, truncated.<sup>1</sup> Suppose, further, that the slope of

each pyramid face to the longitudinal axis was  $24^{\circ}51'$ , as adopted in *Physics of the Air*, for the reasons explained there. Then compute the angular radius of the halo produced by lithium-red light (substantially the kind at the inner edge of the halo to which the measurements in this case were made), refractive index 1.30, through the angle  $65^{\circ}9'$ , between the base of a pyramidal crystal and its side face, figure 2, in which figure a base diagonal is perpendicular to the plane of the paper. The result is  $23^{\circ}42'$ . From this value, in turn, subtract  $15'$ , the radius of the moon, then nearly full and around  $35^{\circ}$  above the horizon, to get the angular distance from the inner (red) edge of the halo to the nearest limb of the moon, the measurement made by Messrs. Stone and Pagliuca. The value thus computed is  $23^{\circ}27'$ , while their measured value was  $23^{\circ}30'$ , a decidedly closer agreement than one reasonably could expect.

If these pyramid crystals had been substantially free from internal flaws and cavities two or three other well-known but unusual halos would have been formed, namely, the  $17^{\circ}6'$  halo (yellow light) and  $31^{\circ}49'$  halo, known, respectively, as the  $17^{\circ}$  halo and the  $32^{\circ}$  halo, if the pyramids had been single, and in addition the  $19^{\circ}$  halo if they had been double. As these halos were not seen<sup>2</sup> the presumption is that at least most of the crystals were large enough to be so filled with cavities (the larger the crystal the greater, in general, its defects, especially in the diagonal planes symmetrical about the longitudinal axis) that light could not pass through their centers in the regular manner it would have passed if they had been solid throughout and flawless. Furthermore, since the halo was equally bright throughout its circumference, the

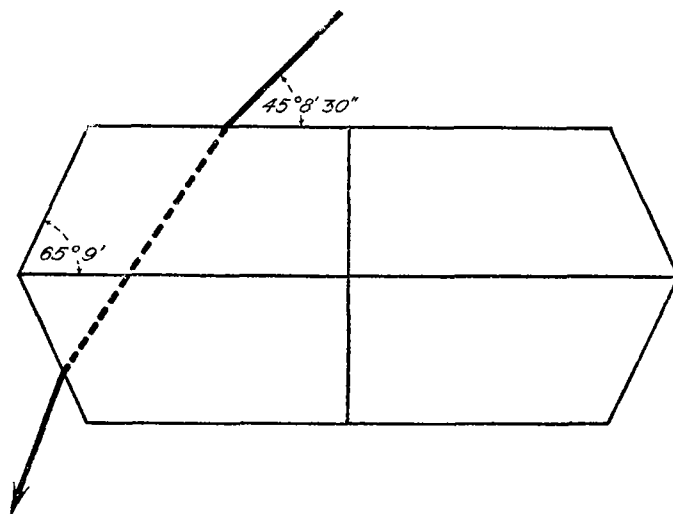


FIGURE 2.—Probable form of snow crystal that produced the Mount Washington, N.H., halo of October 4, 1933.

crystals that produced it evidently fell in random attitudes, and therefore presumably were truncated, double right pyramids, as indicated in figure 2, with lengths between truncate faces considerable fractions of the respective widths—such fractions as would secure irregular attitudes in falling and at the same time, since the halo was quite bright, provide the maximum, or near maximum, amount of properly refracted light.

<sup>1</sup> Scoresby says, on p. 430, vol. 1, of *An Account of the Arctic Regions*, that he saw pyramidal snow crystals only once, but then in large quantity. Dobrowolski reports, in *Results of the Voyage of the Belgica*, having seen frost crystals of these shapes in the Antarctic.

<sup>2</sup> None of them was seen at Mount Washington, though at the same time the  $19^{\circ}$  halo alone was seen at the Blue Hill Observatory in Massachusetts, as reported by Mr. E. M. Harwood in the November 1933 issue of the MONTHLY WEATHER REVIEW—this issue.

We conclude therefore:

1. That the halo in question was the rare  $24^{\circ}34'$  halo listed in *Physics of the Air*, second edition, page 517.
2. That the cirrostratus cloud that produced it consisted largely of pyramidal crystals—probably stubby, truncated double right pyramids.
3. That the slope of the pyramid face to the longitudinal axis is very close to  $24^{\circ}51'$ , as computed in *Physics of the Air*.

Naturally one asks why the snow crystals in such large quantity had this unusual form. Possibly owing to the presence of minute quantities of some impurity, if one might so infer from the sensitivity, in many cases, of crystal form to foreign substances. But that is just a rational surmise. The problem is distinctly one for an interesting investigation.

## THE WINTER OF 1932-33 AT FAIRBANKS, ALASKA

By R. L. FROST

[Weather Bureau Office, Fairbanks, Alaska, Nov. 16, 1933]

[Temperatures in degrees Fahrenheit]

At Fairbanks, Alaska, the first killing frost of the fall of 1932 occurred on September 1 and 3 weeks later the first snow fell. Ice began running in the Chena River on October 14 and the river froze over on the 31st. The first zero or subzero temperature also occurred on the 31st. From the 23d of October to the 14th of March the temperature remained below  $32^{\circ}$ , making 4 months and 3 weeks of continuous freezing weather. There were many days in September and October with freezing temperatures and snowfall, but in the interior of Alaska not that but the freezing over of the rivers is usually considered to mark the beginning of winter. In 1932 the Chena River at Fairbanks froze over on October 31 and the 5 following months are of considerable interest due to the extremely low temperatures recorded. The mean daily temperature during these 5 months was  $-8.7^{\circ}$ . The first dogsled was seen on the streets October 27. It was about this time that airplanes operating over the airways of interior Alaska began using skii landing gear.

November began with a minimum temperature of  $10^{\circ}$  below zero and a maximum for the day of  $5^{\circ}$  above. The highest temperature for the month was  $19^{\circ}$  and the mean of  $8.2^{\circ}$  was  $11.3^{\circ}$  below normal. The highest barometric pressure, 30.55 inches, occurred on the 9th, and the lowest, 28.97 inches, on the 25th, the date also of the maximum temperature. November was the only month during the winter with a temperature of zero or below recorded every day. There were 13 days with maximum temperature below zero. Ice in the river averaged 25 inches in thickness at the end of the month, and just to show what late fall weather is like in the Alaskan interior, Dame Nature ushered it out with a minimum temperature of  $-30^{\circ}$ . The maximum of the last day was  $20^{\circ}$  below zero.

December began with comparatively mild weather. A storm center moved in and the lowest barometric pressure, 29.11 inches, occurred on the 2d. The minimum temperature for the day was  $-12^{\circ}$ . The low-pressure area moved out rapidly and on the 5th the barometer registered 30.94 inches—the highest for the month. On that day the temperature dropped to  $39^{\circ}$  below zero. However, it was not until the 23d that unusually cold weather prevailed. From that date to the end of the month the mean temperature was  $-33.8^{\circ}$ . The maximum temperature for the month was  $27^{\circ}$  on the 9th. There were 30 days with minima zero or lower, and on 14 days the maxima were below zero. The mean temperature for the month was  $-13.1^{\circ}$  which is  $6.9^{\circ}$  below normal. During the last 6 days the total wind movement was but 15 miles, and on the 28th every hour of the day was calm. Ice in the river averaged 37 inches thick at the end of the month.

On December 21 the time of sunrise was 9:58 a.m. and sunset, 1:38 p.m., giving 3.7 hours of possible sunshine.

The altitude of the sun at noon was  $1^{\circ}42'$ . At 10 a.m. the brightest stars were visible in the western sky. On June 21 sunrise was at 12:56 a.m. and sunset at 10:50 p.m., giving 21.9 hours of possible sunshine and 24 hours of daylight. The old year was ushered out with a temperature of  $47^{\circ}$  below zero and a maximum for the day of  $41^{\circ}$  below.

December had been a very cold month but it proved to be a mere sample of what was to come in January. Those who attended the New Year's dance did not loiter long on the streets as the minimum temperature on the 1st was  $-42^{\circ}$  and the highest during the day  $-38^{\circ}$ . The cold spell which began on December 23 continued until January 9, a total of 18 days, during which time the temperature was never above zero. The mean temperature for this period was  $-35.2$ . When the cold spell broke the temperature rose from  $-41$  on the 9th to  $12^{\circ}$  on the 10th. Mild weather prevailed from the 9th to the 23d and during this period 17.8 inches of dry, powdery snow fell. On the 23d day a severe cold wave began and continued to the end of the month. For this period (24th to 30th) the temperature averaged  $-41.1$ . The 27th was a very cold day with a maximum of  $-44^{\circ}$  and a minimum of  $-57^{\circ}$ , but on the following day the thermometer reached  $60^{\circ}$  below zero, a point which was equaled in 1916 but has not been exceeded for 22 years. At 2 p.m. the temperature rose to  $-47^{\circ}$  which was the maximum for the day. For two periods of 14 hours each the temperature ranged between  $55^{\circ}$  and  $60^{\circ}$  below zero. It was then that many people who ventured outdoors had the unique and eerie sensation that occurs when one can hear his breath freeze. As usual on very cold days a dense ground fog prevailed over the city. On this occasion the dense fog persisted for 53 hours. The mean temperature for the month was  $-23.5^{\circ}$  which is  $13.2^{\circ}$  below normal. There were 21 days with maximum and 28 days with minimum temperatures zero or lower. Starting on the 27th and ending on the 29th there was a period of 46 consecutive hours of calm.

Whenever the temperature reached  $-42^{\circ}$  a dense ground fog almost invariably formed over the city. The fog persisted and thickened as the temperature dropped lower and continued until the thermometer rose to about  $-38^{\circ}$  at which point it thinned out to some extent. The highest temperature at which dense fog prevailed was  $-37^{\circ}$ . There were 12 days with minimum temperature  $-42^{\circ}$  or lower. Dense fog occurred on 10 of these days. Light fog was noted on 5 other days. It was interesting to observe the manner in which the fog froze and formed frost crystals on all exposed objects. The telephone wires, trees, and fences became festooned with frost flowers and were very picturesque. This coating of ice flowers often formed an inch or more in thickness and